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**VISUAL DISCRIMINATION PERFORMANCE:
A TRAINING PROCEDURE FOR
THE RESTRAINED MONKEY
(MACACA MULATTA)**

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VISUAL DISCRIMINATION PERFORMANCE: A TRAINING PROCEDURE
FOR THE RESTRAINED MONKEY (MACACA MULATTA)

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FOREWORD
(Nontechnical summary)

This report presents a procedure for training monkeys to perform a series of visual discrimination tasks. A four-stage training procedure was developed with progress from one stage to the next dependent upon specific performance criteria. By following such a procedure it is possible to train monkeys to discriminate between members of a pair of visual stimuli, the resulting performance being both stable and highly accurate. Such behavioral base line is a requirement for assessing the effects of any independent variable, such as irradiation, upon performance. The training procedure described herein also enables an investigator to produce comparable groups of animals for applied behavioral studies.

A BSTRACT

This report describes a procedure for training monkeys to perform visual discriminations and establishes the time required for training. Six male monkeys (Macaca mulatta) were trained to perform a series of visual discriminations to avoid electric shock. Training was accomplished in four stages, with progression from one stage to the next determined by performance criteria, and the data were analyzed with regard to these criteria. It was shown that training in adherence to the procedures produces a stable behavioral base line.

I. INTRODUCTION

Historically, studies of visual discrimination occupy a prominent place in the primate behavioral literature.^{4,7} Much attention has been given to the process by which an animal learns and retains its ability to distinguish between the members of pairs of visual stimuli. Experimental comparisons have been made of the differences in learning to discriminate between (a) three-dimensional objects mounted on a base (stereometric stimuli); (b) objects which are only slightly raised above their base (so-called planometric stimuli); and (c) objects which essentially consist of designs on a flat surface (pattern stimuli). In general, it has been shown that the latter are more difficult for the monkey to learn.^{3,5,12}

In addition to conducting studies of stimulus characteristics involved in discrimination learning, investigators have studied motivational factors involved in such learning. Harlow and his associates have employed reinforcement in the form of preferred foods.^{4,5} Others have used escape from, or avoidance of, noxious or aversive stimulation as reinforcement. Several investigators have used escape from water or avoidance of electric shock to reinforce learning.^{1,2,6,8-11}

The task used in the present study is a simultaneous visual discrimination of pattern stimuli which is reinforced by shock avoidance. This investigation describes a method for training monkeys to perform visual discriminations and standardizes the time factors involved in the various stages of training.

II. METHOD

Six male monkeys (Macaca mulatta) were used in this study. They weighed between 3.2 and 4.4 kilograms at the start of training and were estimated to range in age from 2 to 5 years. The animals were fed fresh fruit and a commercially prepared food twice daily, morning and afternoon. Each monkey was acclimated to a restraining chair two weeks prior to the start of training and was maintained in the chair through the completion of the study.

Following acclimation each animal was trained to discriminate between visual stimuli. The apparatus used in the experiment is described more fully in another report¹ and essentially consisted of a stimulus-response console mounted on the restraining chair and within easy reach of the monkey. Within the console was a speaker and two miniature display cells for the presentation of pairs of visual stimuli. Clear plastic response plates covering the stimuli allowed the animal to respond to them. Relay and solid state control systems were used for the presentation of stimuli and recording of responses.

The stimuli are shown in Figure 1. The first five problems used stimuli that were white forms on a black background. The last two pairs were colors on a black background. The stimuli were presented in invariant serial order. There were two stimulus conditions, A and B, in which opposite pair members were designated correct (Figure 1). Three animals were trained under each condition. The position of the correct stimulus was determined by a repeated series of 63 alternations balanced to insure an equal number of correct stimuli appearing randomly at each position.

PROBLEM	CONDITION A		CONDITION B	
	CORRECT	INCORRECT	CORRECT	INCORRECT
SINGLE STIMULUS	1	□		○
PAIRED STIMULI	2	□	○	○ □
	3	✗	△	△ ✗
	4	—	+	+
	5	(WH)		(WH)
	6	(YEL)	(BL)	(BL) (YEL)
	7	(GR)	(RED)	(RED) (GR)

Figure 1. Stimuli for the two-choice discrimination task

A trial was initiated by the simultaneous illumination of the stimuli and the house light (15-watt incandescent bulb). The stimuli were presented for 20 seconds. If the monkey responded to the correct stimulus during this interval, the stimuli and house light extinguished for 2 seconds (the short time out). If the monkey failed to respond within 20 seconds or responded to the incorrect stimulus, the stimuli extinguished but the house light did not, a 10-second tone was initiated, and a brief shock to the feet was delivered 5 seconds after the beginning of the tone. The shock source was adjusted for each monkey to produce the avoidance behavior.

Trials were presented on a given problem until 10 consecutive correct responses occurred. At this point the house light and stimuli extinguished for a 3-minute rest period (the long time out). Subsequent and identical work periods were then alternated with 3-minute rest periods. This work-rest sequence was followed for 2 hours each day. There were four stages in the training procedure, as discussed below.

Stage 1 - Single Stimulus Discrimination Training. The initial behavior was developed by the following procedure. With manual control of the programmed relay system, the experimenter presented the correct member of the first stimulus pair to the monkey and terminated the stimulus upon observing any behavior which was a component of the desired final response. The termination of the stimulus was immediately followed by the 2-second period of darkness. This 2-second period served as a reinforcement for an acceptable response. By requiring the animal to more and more closely approximate the final desired response, the behavior of depressing the key covering the stimulus was gradually developed. During this stage 10 consecutive correct responses resulted in the long time out, which also reinforced the desired behavior. This stage ended when the animal reached a criterion of 90 percent correct responses for a minimum of 20 trials.

Stage 2 - Paired Stimulus Discrimination Training. During this stage, the incorrect stimulus of Problem 2 (the first pair) was introduced in graduated steps of increasing brightness. Initially, the incorrect stimulus was imperceptible to the human eye because of resistors in series with the projector lamp. The resistance was reduced in eight steps until the stimuli of the pair were of approximately equal brightness. Reduction in resistance occurred when the monkey had achieved the accuracy criterion (90 percent correct for at least 20 trials) on the prior step. At this point the incorrect stimulus was said to have been "faded-in." When this had occurred and the animal was responding at the criterion of 90 percent correct for 30 trials, the next pair (Problem 3) was introduced (with the incorrect member in series with the resistance) and the above training procedure again followed. Four

repetitions each requiring 10 consecutive correct responses were given daily on previously learned problems. This stage ended when the monkey had learned Problems 2 through 7 to the criterion of 90 percent correct for 30 trials.

Stage 3 - Stabilization Training-Error Reduction. This stage, considered to be a practice or stabilization period, consisted of approximately 2 hours of training per day and lasted at least 6 days. Four repetitions of 10 consecutive correct responses (each repetition followed by a long time out) were required on each of Problems 2 through 7.

Stage 4 - Final Stabilization Training. A minimum of 6 days of training comprised the final stabilization period during which the problem was changed after 10 trials. The requirement of 10 consecutive correct responses prior to the long time out was discontinued. The monkey, regardless of correct or incorrect responses, now received only 10 trials per problem before presentation of the next problem. Each problem was followed by a 3-minute time out. The single stimulus was added as a separate problem (Problem 1) at the beginning of this stage, thus making a total of seven problems. On each day of training (about 2 hours), four sets of Problems 1 through 7, 10 trials each, were presented for a total of 280 trials per day.

III. RESULTS

Stage 1 - Single Stimulus Discrimination Training. The criterion for acceptable performance was 90 percent correct responses out of 20 trials. The mean number of trials to criterion, together with the ranges for each of the six correct stimuli of Problems 2 through 7, are shown in Figure 2. The mean number of trials

to reach criterion decreased from approximately 600 trials on the single stimulus of the first pair (Problem 2) to approximately 30 trials on the single stimulus of the last pair (Problem 7). The range for all monkeys to reach criterion on a given single stimulus decreased from over 1000 trials on Problem 2 to approximately 40 trials on Problem 7.

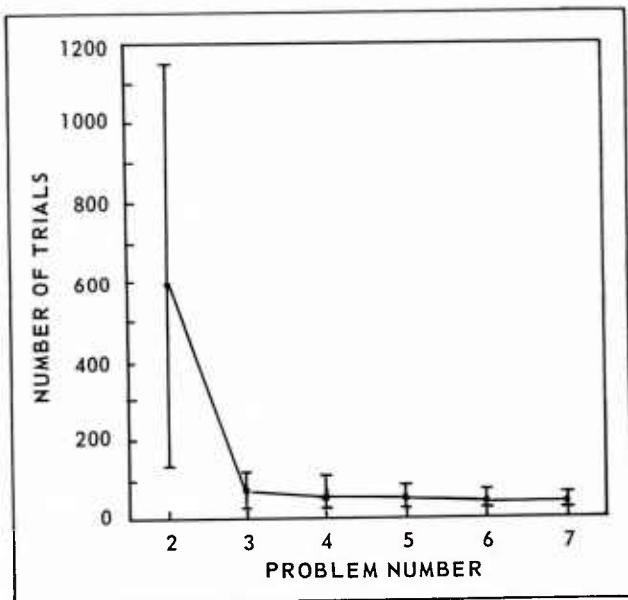


Figure 2. Mean and range of trials to criterion on correct stimulus of Problems 2 through 7 (Stage 1)

Stage 2 - Paired Stimulus Discrimination Training. The training data were analyzed from initial presentation of the single stimulus of each problem until responses to the paired stimuli (with both members of approximately equal brightness) were 90 percent correct over 30 trials.

Figure 3 indicates the mean and range of trials to criterion for Problems 2 through 7. The mean number of trials to reach criterion dropped from 1823 trials on Problem 2 to 273 trials on Problem 7. The range tended to decrease as training progressed.

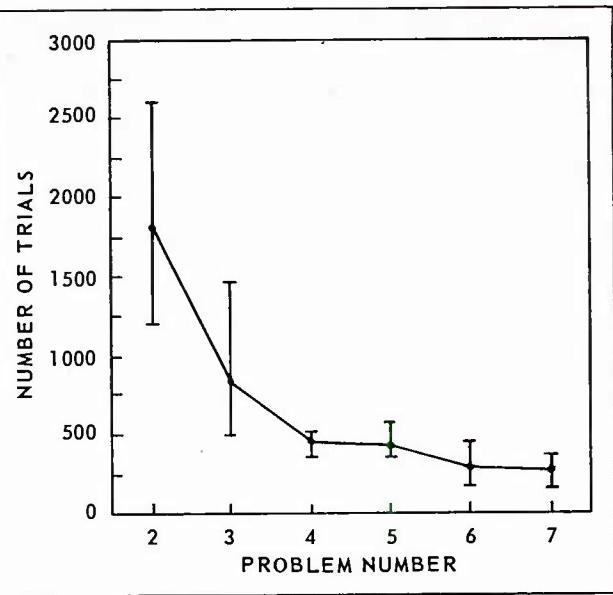


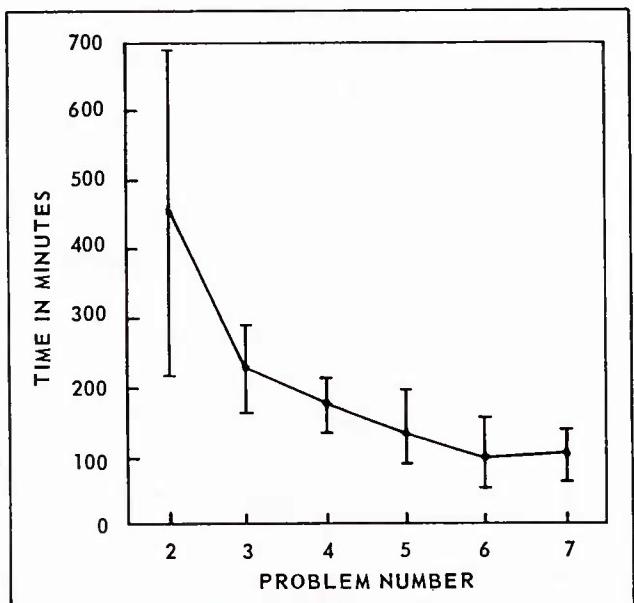
Figure 3. Mean and range of trials to criterion per problem (Stage 2)

Figure 4 shows the mean and range of time to criterion on Problems 2 through 7.

There was again a general decrease in means and ranges for successive problems.

The mean time needed for reaching criterion on Problem 2 was 458 minutes (range = 216 to 687 minutes), while the mean time for Problem 7 was 101 minutes (range = 61 to 141 minutes).

Figure 4. Mean and range of time to criterion per problem (Stage 2)



Stage 3 - Stabilization Training-Error Reduction. Figure 5 shows the performance at this stage in terms of percentage of correct responses. With each subject receiving a minimum of 240 trials per day on Problems 2-7, the mean percent correct did not drop below 94 for any given day and averaged 98 percent over all days. The limits of the range for all six days of training were approximately 91 and 100 percent.

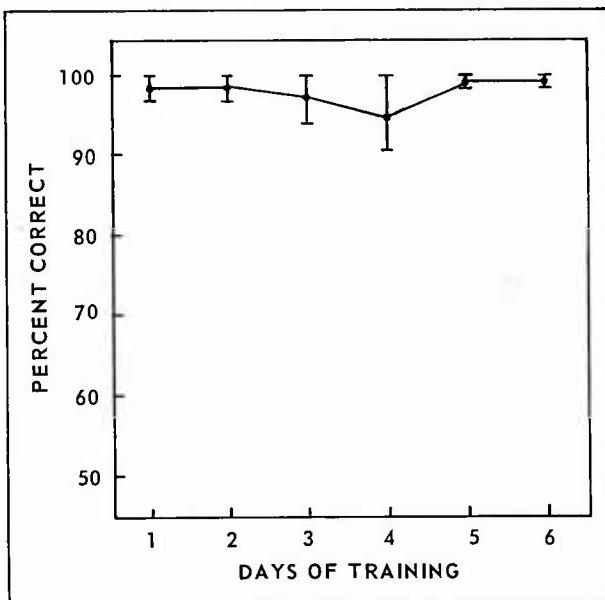


Figure 5. Stabilization training-error reduction (Stage 3)

Stage 4 - Final Stabilization Training. The performance in this stage, based on all seven problems with a minimum of 280 trials per day per animal, is shown in

Figure 6. The mean percentage correct for all six animals over the 6 days was 99.

For single days the mean percentage correct for all six subjects was 97 or above, with the range for various days extending between 94 and 100 percent.

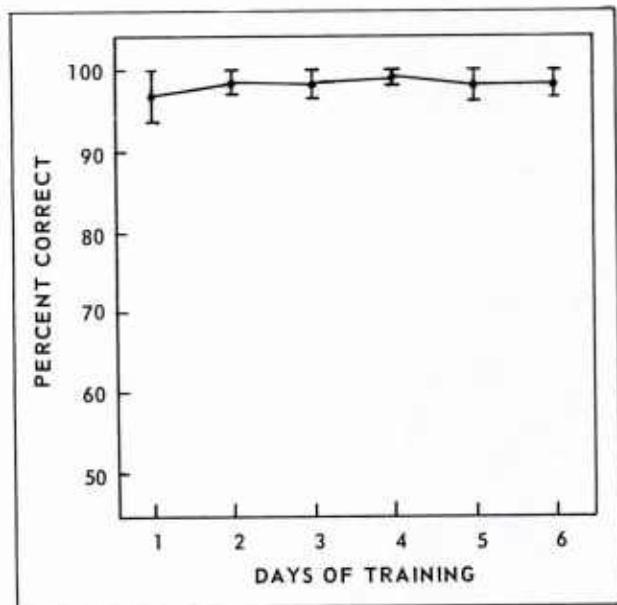


Figure 6. Final stabilization training

IV. DISCUSSION AND CONCLUSION

The results of this study show that, with the implementation of the procedures described, a high and stable level of performance can be obtained in 44 days. This figure is based on the 2-week acclimation period prior to training, plus the average amount of time required by the animals to progress through all stages of training when one 2-hour training session is presented each day.

Analysis of the data has delineated the time factors in the visual discrimination task under standardized procedures. This information enables the experimenters to

train comparable groups of animals in a known time frame. With limitations on facilities, behavioral control apparatus, and manpower, the total training time for this task becomes critical for the programming of efficient research schedules.

In order to train the maximum number of monkeys in the shortest possible time, it is important to know the time required to reach criterion at each stage of training. The average time spent in each stage must be known to train several monkeys simultaneously. In this connection, it is also important to note, as the results demonstrate, that as training progresses the efficiency of learning increases. To achieve the stated objective a training schedule must be planned which considers both of these factors.

Furthermore, the ability to produce comparably trained groups of animals (both in terms of standardized procedures and training time) is essential to evaluate the effects of any independent variable, such as irradiation, on visual discrimination performance.

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13. ABSTRACT

This report describes a procedure for training monkeys to perform visual discriminations and establishes the time required for training. Six male monkeys (Macaca mulatta) were trained to perform a series of visual discriminations to avoid electric shock. Training was accomplished in four stages, with progression from one stage to the next determined by performance criteria, and the data were analyzed with regard to these criteria. It was shown that training in adherence to the procedures produces a stable behavioral base line.

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